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## **BASIC INFORMATION ON MPI AND ARMAKAP**

### **Overview**

MPI is a Magnesium Phosphate based ceramic cementitious product manufactured by MagPhos, Inc. of Raleigh, North Carolina with many superior properties compared to conventional Portland cement. ArmaKap is a customized version of MPI with special additives to enhance the radiation attenuation of MPI while maintaining the unique advantages of MPI. It is manufactured by ArmaKap, Inc. which is a separate company but closely aligned with MagPhos, Inc.

### **Executive Summary**

The use of Magnesium based cement products date back to ancient times, but over the years they have been largely replaced by Portland cement due to its abundant availability and low cost. The pioneering research and development of shielding enhanced magnesium phosphate ceramic cement was done at Argonne National Laboratories in Lamont Illinois about 20 years ago. Further development of related products has continued largely by private industry to the point that today's version of MPI and ArmaKap has undergone several generational improvements compared to the material of a couple decades ago. These improvements involve not only formulation, but also process control and raw material selection. The result is now a very consistent product.

Privately funded testing work on samples of advanced versions of attenuation enhanced ceramic cement supplied by ArmaKap has been completed in 2018 by the Nuclear Engineering Department at North Carolina State University. These tests have been very encouraging and show a significant improvement of gamma ray attenuation, up to as much as 86%, depending on the energy level of the radiation and the required strength of the final product.

**The many unique advantages of MPI coupled with the radiation attenuation of ArmaKap offer a new material to scientists and engineers looking for these characteristics in a cement type product for shielding, storing, and transporting radioactive waste.**

Additional information of the characteristics of MPI and the recent testing work on ArmaKap is the subject of this report.

### **Advantages of MPI Compared to Portland Cement**

#### **Basic Chemistry**

While Portland cement and MPI are both cementitious products they are quite different in their chemistry. The differences are complex, but simply stated the CaO of Portland cement is largely replaced MgO in MPI. Also, when the phosphate is added the curing process converts from a hydration process with Portland cement becoming an acid-base exothermic reaction with MPI. These changes significantly alter (improve) the characteristics of MPI. Like Portland cement, MPI is usually used in conjunction with various aggregates making MPI Concrete. The aggregates may be conventional such as sand, gravel, crushed stone, marble chips, etc. Or

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with MPI they may be unusual materials such as wood chips, burlap, paper, synthetics, or even recycled matter. This allows great flexibility in the design of the material to be used depending on the need.

### **Greater Strength**

Typical compressive strength of Portland cement varies from 2,000 to 4,000 psi and for MPI from 4,000 to 8,000 psi. The aggregates and additives used allow for design flexibility depending on the need.

### **Superior Bonding Strength**

Fresh Portland cement is notoriously poor at bonding to cured Portland cement and multiple pours result in "cold joints. MPI creates both a mechanical and a covalent (chemical) bond between the adjacent substrate. Generally the bond strength is comparable or greater than the strength of the material itself. The importance of this in nuclear containment applications should not be overlooked.

### **Lighter Weight**

MPI is approximately 15 to 20% lighter than comparable volumes of Portland cement. This is of importance in designing shipping containers.

### **Lower Coefficient of Expansion and Contraction**

This occurs both during curing and in service. Everyone is familiar with designed periodic sidewalk "joints" created to cause the Portland cement based concrete to crack at predetermined locations. These cracks occur due to expansion and contraction of the concrete with temperature changes. MPI based concrete, for complex chemical reasons, show only a very small percentage of the expansion and contraction with temperature changes by comparison. Further, Portland cement is subject to "hydration cracking" during the curing process. MPI cures by an acid-base reaction and does not suffer from this problem. This ability to resist cracking is critical in nuclear waste containment applications.

### **Cures in Sub-freezing Temperatures**

The acid-base curing reaction of MPI is highly exothermic reaching temperatures of 130° to 150° allowing it to cure in sub-freezing weather.

### **Highly Water Resistant (Waterproof)**

This characteristic is maintain when used with sand aggregate and applies to both fresh and salt water. In nuclear containment applications this is critical to both keep water out and liquids in. Water will penetrate conventional Portland cement quite easily over time.

### **Higher Flexural Strength, Shear Strength, and Impact Resistance**

The basic strength of MPI is further enhanced by the aggregate used. Specific data is available upon request.

### **Resistance to Fire and Heat**

MPI has been subjected to temperatures of 2000° F for 4 days with no loss of integrity. It has passed the very sever ASTM E119 Test Standards (heated to1950° F and then blasted with a cold water fire hose without failure).

### **Acid and Alkali Resistant**

MPI is unaffected by pH ranges from 3 – 11.

### **No VOC**

MPI emits no Volatile Organic Compounds either during curing or in use.

### **Fast Setting – High Early Strength**

MPI sets very rapidly with typical working times of 5 to 15 minutes. This time may be increases during cold weather and may be made longer through mixing with ice water and using certain additives. It reaches 80% of its design strength in a few hours and full strength within a day allowing rapid return to service or quick removal from molds in cast applications.

### **Can be Poured, Sprayed, or Troweled**

MPI lends itself to all application techniques. It can be self-leveling upon initial pour when this is desirable.

### **Cures Under Water**

MPI can be poured underwater when this is required.

### **Environmentally Friendly Green Product – None Toxic**

MPI is a totally green product with a low carbon footprint. No kiln is used in its manufacture. Normal precautions are necessary to prevent inhalation of the unmixed powder. The Material Safety Data Sheet is available.

### **ArmaKap Radiation Attenuation**

Tests have recently been completed at the Department of Nuclear Engineering at North Carolina State University on ArmaKap, a variation of MPI designed to enhance its gamma ray shielding. The attenuation of various energies was measure using a spectrometer and multi-energy radiation sources. (Cs137, Ba133, Co60). Graphic analysis of attenuation verses energy and its effect of compressive strength were presented and are available. A maximum attenuation 86% greater than Portland cement was achieved at energy of 356Kev while maintaining strength similar to conventional Portland cement.

**Note – specific test results for all of the above parameters vary depending on the mix specifications and aggregates used. Back up data is available.**

### History

According to George Swanson and many other experts in the field of MgO cements, "blends of MgO were used in ancient times in Germany, France, Mexico, Latin America, Switzerland, India, China and New Zealand, among other countries. The Great Wall of China and many of the Stupas in India which are still standing today were all made with Mg-based cements. Ancient European artisans used a timber frame with MgO infill in constructing homes. No gaps are visible in these 800-year-old walls that still remain in use". These were obviously very basic metal oxides and phosphates (or other weak acids) but they did provide sustainable cements for these and other historic building projects. In the past 20 to 30 years there has been a resurgent interest in these ceramic cements based on the unique properties not found in Portland Cements.

### Economics

MPI a premium product compared to Portland cement, but when its labor saving characteristics, long life, and its maintenance free nature are considered it is very competitive. ArmaKap costs vary depending on the design characteristics desired and the cost of the additives used.

### Availability

**New Solutions, LLC is the International Marketing Agency for MPI and has exclusive marketing rights for ArmaKap. Contact Information:**

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